Annual Report 2016

Jožef Stefan Institute, Ljubljana, Slovenia

DEPARTMENT FOR ADVANCED MATERIALS K-9

In the Department for Advanced Materials we investigate novel materials through an understanding of the mutual dependence of their structural, microstructural and functional characteristics. Modern technologies that enable the synthesis of materials with atomic and microscale precision are used to prepare pre-designed structural 3D materials, thin films and nanoparticles with the desired crystal structure, chemical composition, microstructure and morphology. Among our important objectives is the development of: i) novel functional oxide materials for various electronic applications, ii) new materials with improved antibacterial and photocatalytic effects and iii) new materials for efficient energy conversion.

Head:
Prof. Danilo Suvorov

Functionalized oxides for electronic applications

In our study of the mechanisms for controlling the size of ferroelectric perovskite particles with an anisotropic shape of the plates there were two main directions. In the first part, the main emphasis was on control of the morphology of $Bi_4Ti_3O_{12}$ and $Bi_{3.8}Nd_{0.2}Ti_3O_{12}$ nanoplates (side length ~100nm, thickness ~10 nm) under hydrothermal conditions. The former types of plates were used as the template for a topochemical conversion into perovskite ($BaTiO_3$, $SrTiO_3$) nanoparticles with the shape of blocks and plates, while the latter composition was prepared mainly due to a study of their behaviour in a liquid crystal. In the second part, we studied the mechanisms of the topochemical conversion from μm- and nm-sized $Bi_4Ti_3O_{12}$ plates into $BaTiO_3$ and $SrTiO_3$ in a molten salt or under hydrothermal conditions.

A study of the topochemical conversion of $Bi_4Ti_3O_{12}$ nanoplates into $BaTiO_3$ in a molten salt was focused on the preservation of the nanodimensions of $BaTiO_3$ during heating to high temperature, which is needed for the increase of tetragonality, and consequently the ferroelectricity. For the growth of $BaTiO_3$ nano-plates, nano-blocks due to Ostwald ripening were retarded based on the fact that the rate of the dissolution and growth of the particles with flat and smooth faces is slower than those with an irregular shape and high curvature.

The topochemical conversion of layered Aurivillius $Bi_4Ti_3O_{12}$ into $BaTiO_3$ or $SrTiO_3$ perovskite under hydrothermal conditions has not been reported yet. Previous results imply that it is possible to affect the prevailing growth mechanism and thus tune the reaction towards the target morphology by controlling the synthesis conditions (Figure 1). In order to preserve the anisotropic shape of the $Bi_4Ti_3O_{12}$ plates, the growth of the perovskite on these plates should be layer-by-layer (Frank-van der Merwe). Additionally, it is assumed that control over the reaction conditions for the layer-by-layer growth will also be crucial for the preparation of the composite plates of $BaTiO_3/SrTiO_3$, which are expected to exhibit enhanced ferroelectric properties due to the lattice strains, which result from the lattice mismatch. Consequently, the ferroelectric polarization of $BaTiO_3$ grown on (100) oriented $SrTiO_3$ plates is assumed to point perpendicular to the plate surface, which is required in several applications. Ferroelectricity is also expected to be preserved down to smaller dimensions of the $BaTiO_3/SrTiO_3$ nanocomposite plates, which makes them very useful building blocks for the fabrication of nanometric electromechanical devices.

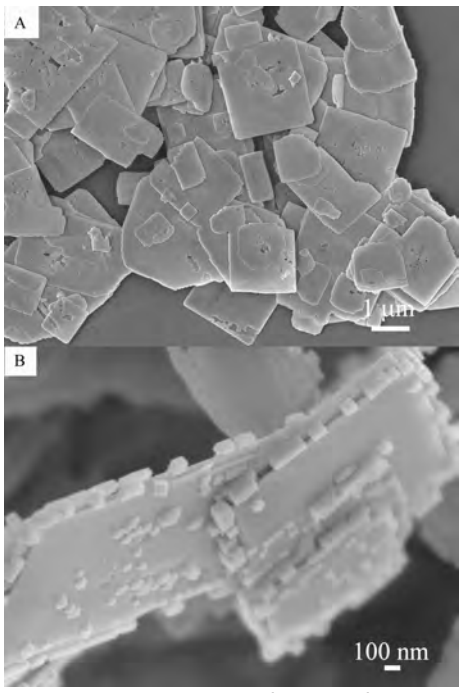

Figure 1: Topochemical transformation from $Bi_4Ti_3O_{12}$ plate-like particles into $SrTiO_3$ under alkaline hydrothermal conditions with the dominance of the growth similar to a) Frank-van der Merwe (layer-by-layer) and b) Volmer-Weber (island formation).

The integration of epitaxial complex oxides with Si represents an invaluable opportunity for the creation of novel devices with logic and sensing capabilities, both implemented in the same chip. Using PLD we grew epitaxial ultra-thin (3–4-nm) $SrTiO_3$ (STO) layers on Si(001), showcasing the possibilities of this technique for the growth of templates for the integration of complex oxides with Si. Our procedure involves the growth of a 1/2 monolayer (ML) of Sr buffer layer on the reconstructed Si(001) surface by PLD, the deposition of STO in an inert Ar atmosphere, and latter oxidation and crystallization phases (Figure 2). The optimization of STO deposition, oxidation, and crystallization parameters proves to be essential for the improvement of the layer's quality. It has been found that the minimization of the thermal budget during the crystallization phase increases the interface sharpness, but a minimum temperature is needed for a proper densification of the STO layer. A coverage of 2 ML before every crystallization and oxidation phases was determined as the best balance between the critical thickness, minimization of the thermal budget, and a proper coverage of the buffer layer, which prevents its reactions with the Sr/Si surface. These results improve the general knowledge and understanding of metal oxide/silicon heterojunctions,

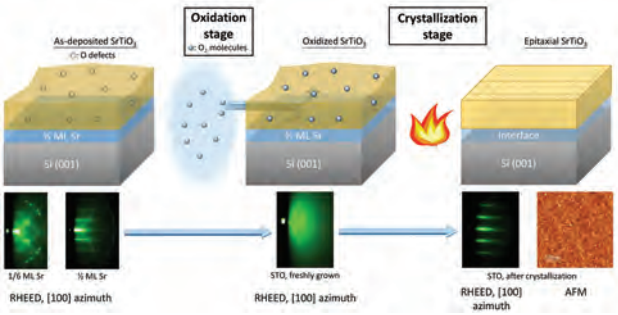

Figure 2: Graphical scheme of the STO growth process. The STO is grown on the 1/2 ML Sr/Si surface, and it consists of STO deposition, oxidation and crystallization phases, which are adjusted to minimize interface reactions and to obtain the most optimal crystalline quality. Below the scheme, RHEED patterns can be seen for the deposition of the Sr buffer layer (left), the freshly grown STO (center) and the crystallized STO (right), along with an AFM image after the final stage of the growth process.

and represent a solid stepping stone for the growth of high-quality, thin STO templates on Si by PLD.

In our work we have studied the structural properties of a strontium buffer layer on silicon grown by the PLD technique. The samples were prepared in a vacuum chamber with a base pressure of 2×10^{-9} by first removing the native SiO_2 layer by flash annealing at 1200 °C, followed by the deposition of half a monolayer of strontium. *In-situ* characterization by reflection high-energy diffraction showed a typical two-domain (2×1)+(1×2) reconstruction. In order to ensure an adsorbate-free surface the samples were transferred using an ultra-high vacuum suitcase. The samples were analysed by low-energy electron diffraction (LEED) and scanning tunnelling microscopy (STM). LEED analysis confirmed that the surface reconstruction was preserved during the transfer. High-resolution STM images revealed a highly ordered surface, which has a quality comparable to a surface prepared using a more established molecular beam epitaxy technique (Figure 3). This study presents the first local structural analysis on of the Sr/Si surface prepared by PLD on the atomic scale.

We used PLD technique to prepare $Pb[Mg_{1/3}Nb_{2/3}]O_3$-$PbTiO_3$ (PMN-PT) thin films on single-crystal $SrTiO_3$ substrates as well. PMN-PT exhibits excellent piezoelectrical properties, however, only in the absence of the pyrochlore phase, which can form due to lead-loss during the synthesis. We prepared single-phase PMN-PT films by optimizing the deposition conditions and by using PbO-excess targets. The (00l)-peak splitting in the X-ray diffraction spectra revealed a strong influence of the process pressure on the domain structure of the films, which was confirmed by high-resolution transmission electron microscopy. In the next stage we deposited thin-film electrodes ($SrRuO_3$ or $LaNiO_3$) between the STO and the PMN-PT. We found that the electrode layer (especially $LaNiO_3$) has a pronounced influence on the further growth of PMN-PT by stabilizing the formation of the perovskite phase.

Antibacterial and photocatalytic materials

The group for biomaterials has been working on fields including the development of innovative antimicrobial coatings, the development of new antimicrobial biomaterials and innovative techniques for cryopreservation.

We have developed an innovative composite coating system consisting of 1D nanostructured MgO incorporated within the PLGA matrix. We detected the presence of a strong interphase interaction between MgO and PLGA, which resulted in the retention of MgO nanoparticles at the surface of MgO/PLGA coatings. As a consequence, the MgO/PLGA coating was able to prevent *S. epidermdiis* colonization without exhibiting any change to the attached red blood cells. We concluded that the stabilization of MgO within PLGA matrix widened the "therapeutic window" of magnesium oxide particles.

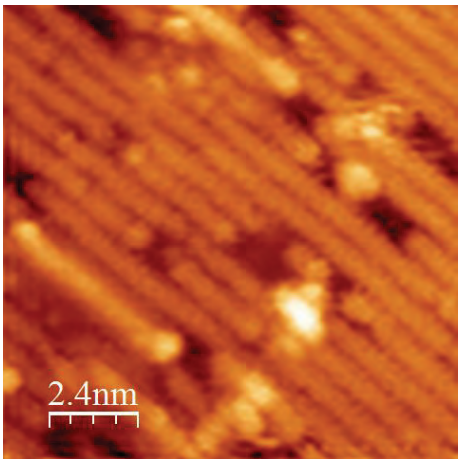

Figure 3: Filled electron state STM image of the Sr/Si(001) surface exhibiting a (2×1) reconstruction. In the filled electron state image, the tunneling current is related to the Si dangling bonds of the Si dimer chains participating in bonding with Sr atoms sitting in-between the dimer chains (T=60 K, U=-3V, I=200 pA).

We continued our research on nanocomposite materials based on gallium, gold and hydroxyapatite. A nanocomposite of Ga and hydroxyapatite was compared to a nanocomposite of Ag nanoparticles and hydroxyapatite. The new gallium-based nanocomposite was more effective against *Pseudomonas aeruginosa* and less toxic to L929 as well as IMR-90 fibroblasts (Figure 4 and 5). We also investigated the influence of the size and size distribution of the Ga nanoparticle and Ga content on the antibacterial activity and cytotoxicity of the nanocomposite and optimised its synthesis. We could obtain a very narrow size distribution by using oleic acid as a surfactant and thermal decomposition to create Ga nanoparticles. Nanocomposites with such Ga nanoparticles exhibited a stronger antibacterial effect, but also an increased toxicity in comparison with the nanocomposites prepared by ultrasonic emulsification without any surfactant. Based on our discoveries on the incorporation of Ga^{3+} ions into hydroxyapatite, we have developed an optimum nanocomposite of functionalised Au nanoparticles and Ga(III)-containing hydroxyapatite, which effectively stops the growth of *P. aeruginosa, E. coli* and *S. epidermidis* bacteria and has low toxicity for L929 fibroblasts. Apart from these achievements we have also made very interesting findings about the mechanism and optimisation of the formation of functionalised Ga/Au core-shell nanoparticles and discovered possibilities for their stabilisation. The results of this research, which were published in three research articles, have been selected for an illustration of the Journal of Materials Science: Materials in Medicine.

The research in the field of new biomaterials that combine antimicrobial and magnetic properties was initiated in 2016 in the framework of a bilateral project with Serbia. In this field, we have developed new processes for the synthesis of composites that combine the functionalized nanoparticles of gold (Au-arginine) and ferrite nanoparti-

cles (MFe_2O_4, M = Zn^{2+}, Co^{3+}, Cu^{2+}). We have shown that the new composites possess a strong antimicrobial activity (against *E. coli* and *S. epidermis*), enabled by functionalized gold, and magnetic properties, which were enabled by ferrite nanoparticles. In spite of the nano-size (20-nm Au particles having 5-nm particles on their surfaces), we showed that the composite particles do not cause damage to blood cells and have shown to be very promising for further research in biomedical applications.

In the field of innovative techniques for cryopreservation we started research on the development of biomimetic inorganic calcium hydroxyapatite (HAp) nanoparticles for the delivery of bioactive payloads in cells. Our research was focused on cell cryopreservation for blood-transfusion applications and the developed HAp nanoparticles were used for the delivery of natural cryoprotectant trehalose in erythrocytes, which lack the endocytosis machinery. The work involved studies of the relationship between nanoparticle properties and their efficiency for trehalose delivery in cells and on the mechanism of interactions between nanoparticles and the cell membrane. The studies have shown that HAp nanoparticles are efficient agents for the delivery of trehalose in erythrocytes and strongly enhance the cryo-survival of erythrocytes after freeze-thawing. From this area we applied for a Marie Curie research project that was awarded with a "Seal of Excellence" from the European Commission.

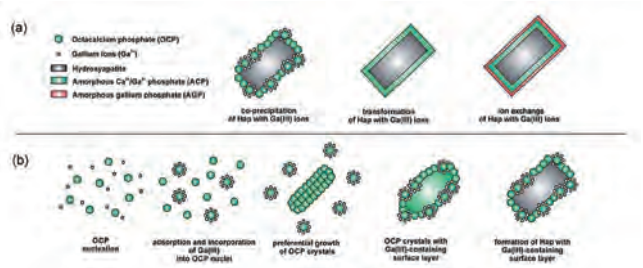

Figure 4: a) Illustration of the structure of HAp(Ga) obtained by co-precipitation, transformation and ion exchange with Ga3+ ions and b) the mechanism of formation of HAp(Ga) co-precipitated nanocrystals.

New materials for efficient energy conversion

In the scope on the research on new materials for energy conversion we investigated compounds with a layered crystal structure that comply with the "phonon-glass, electron-crystal" concept and are thus interesting for the development of new thermoelectric materials. In the case of materials based on layered titanium disulphide we developed a process that allows the synthesis of a highly stoichiometric compound, which leads to a wide range of possibilities regarding the formation of intercalated bulk materials with improved electrical and thermal transport properties. Furthermore, we optimized a high-pressure pulsed electric current sintering process that resulted in highly textured, twinned bulk materials based on titanium disulphide with an order of magnitude lower thermal conductivity.

In the case of bulk materials based on layered cobaltates we found that crystal structure changes within individual grains can be triggered by changing the atmosphere in the predicted operating temperature range. The findings contribute to a new understanding of the crystal chemistry of layered compounds as candidate materials for thermoelectric energy conversion.

Within the research field of energy-conversion materials we also studied crystal-structure and domain-texture changes induced by external mechanical stresses and electrical fields. For the studies, we applied *in-situ* X-ray diffraction and *in-situ* transmission electron microscopy to the lead-free piezoceramics. We found that induced changes depend on the initial state of the material. The study contributed to an understanding of the coupling between structural changes, which is crucial for development of new environmentally friendly piezomaterials.

Materials for heat-insulation applications

Our research focused on the development of insulation materials with improved insulation capacity, temperature stability, and/or improved sustainability. We investigated foaming mechanisms for various glass cullets and identified additives that enable the tuning of the foaming process in the preparation of foam glasses. Selected additives facilitate the preparation of foam glass from cullets of cathode-ray-tube (CRT) panel glass, flat glass, container glass as well as their mixtures under very similar process conditions (Figure 6). A decreased dependence of the foaming process on the composition of the glass is an important scientific and industrial contribution. Foam-glass products with a high content of container glass were open porous, suitable for use in sound insulation. Closed-porous foams are suitable for load-bearing, age-resistant thermal insulation within the whole lifespan of the building. The thermal conductivity of the foams with a higher content of the CRT panel glass (Figure 7) was lower than that of the foams with the container or bottle glass. The lowest achieved thermal insulation values are 39–40 mW/(m·K). We also measured the thermal conductivity of the solid structure in an evacuated open-porous sample, which revealed the approximately 50 % contribution of the solid conductivity to the effective thermal conductivity.

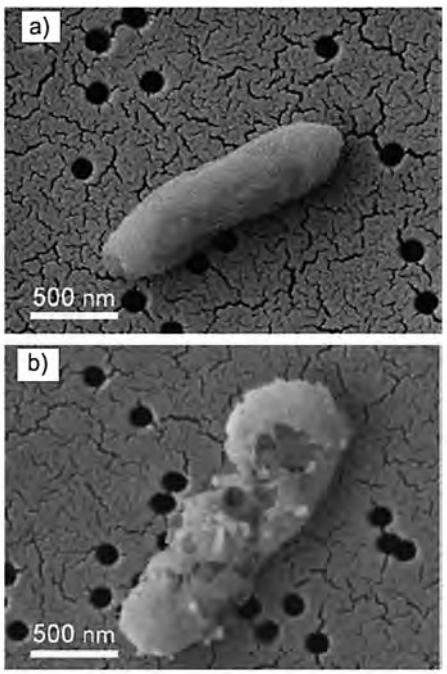

Figure 5: Bacterial morphology: a) SEM image of P. aeruginosa MW1 after 24-h incubation in growth medium with 0.5 mg/mL hydroxyapatite and b) SEM image of P. aeruginosa MW1 after 24-h incubation in growth medium with 0.1 mg/mL of Ga@HAp.

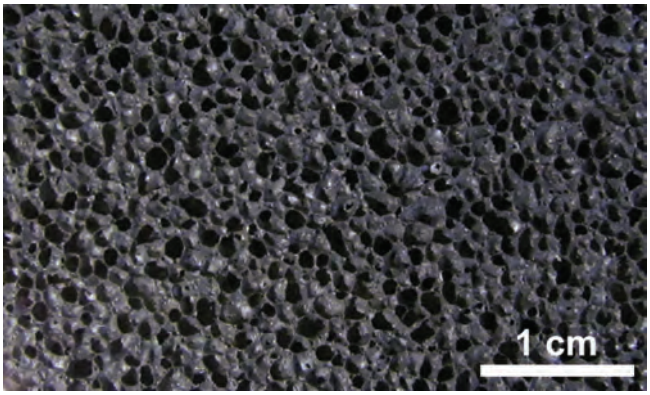

Figure 6: Microstructure of a foam glass with 95 % porosity prepared from waste window glass.

ENPIEZO

In the scope of the M-ERA.NET project ENPIEZO we are developing piezoelectric-based energy-harvesting (EH) devices to provide a remote source of electricity from waste vibrations. We are investigating the fabrication-friendly pulsed-laser deposition of high-quality epitaxial $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) thin films on Si, based on the delicate engineering of silicon-oxide interfaces. The study, joining laboratory- and industrial-scale systems, is the first of its kind. On our laboratory system we thoroughly studied the Sr-reconstructed Si surface and optimized the crucial growth parameters of $SrTiO_3$ (STO) on Si. Separately, we optimized the growth on PMN-PT thin films on single-crystal STO substrates, whereupon we started integrating the two systems. Within this project we are also studying the preparation of polycrystalline PMN-PT films by aerosol-deposition on stainless-steel substrates. In the past year mathematical modelling of the piezoelectric transducers was also completed. Simultaneously, we investigated various potential applications for these transducers.

EPCOS

For our industrial partner EPCOS OHG, Deutschlandsberg, Austria, in the past year we have carried out the project: "Devices for energy storage based on PLZT thin films and Cu electrodes". We grew PLZT thin films using a laboratory and industrial system for pulsed-laser deposition. On Si substrates with a diameter of 150 mm we successfully controlled the chemical homogeneity of all the present elements, as well as the layer thickness along the substrate. Further development of advanced devices for energy storage in electronic applications will be based on the results of this project.

SCOPES

Within the SCOPES project, which is trilateral cooperation between Serbia, Slovenia and Switzerland, we have developed new methods for forming porous structures which are suitable as carriers of stem cells and are useful in tissue engineering. Such structures include a polymer matrix (made up of a series of new biocompatible and biodegradable polymers, which we developed together with the TMF partner in Serbia) and the inorganic particles are based on doped apatite (which includes ions such as Mg^{2+}, Zn^{2+}, Ga^{3+} and Sr^{2+}). In the first phase of materials testing (which was made in the ETH within a cooperation with a partner in Switzerland), we have shown that the presence of ions has a strong influence on the different stages of the cell life cycle of stem cells and stimulates their differentiation and growth.

Figure 7: Cross-section images of the foam glasses prepared from panel glass powders with different particle sizes. The density of the foam glass prepared from 13-μm powders is 120 kg/m³.

CleanTechBlock II

Project CleanTechBlock II – energy-saving facade building component develops and demonstrates a new building block with improved foam glass insulation core and clay brick shells. The goal of the project is to demonstrate the new foam-glass preparation process on a larger scale (size 1:1) and preparation and thermal insulation property testing of a wall segment from the new building blocks.

Some outstanding publications in the past year

1. Jakob Koenig, Rasmus R. Petersen, Yuanzheng Yue, "Influence of the glass particle size on the foaming process and physical characteristics of foam glasses", J. non-cryst. solids, vol. 447, str. 190-197, 2016, doi: 10.1016/j.jnoncrysol.2016.05.021.
2. Lei Li, Matjaž Spreitzer, Danilo Suvorov, "The microstructure, dielectric abnormalities, polar order and microwave dielectric properties of $Ag(Nb_{(1-x)}Ta_x)O_3$ (x = 0-0.8) ceramics", J. Eur. Ceram. Soc., vol. 36, no. 14, str. 3347-3354, 2016, doi: 10.1016/j.jeurceramsoc.2016.05.017.
3. Vojka Žunič, Mario Kurtjak, Danilo Suvorov, "Bifunctional bridging linker-assisted synthesis and characterization of TiO_2/Au nanocomposites", J. nanopart. res., vol. 18, no. 11, str. 336-1-336-11, 2016.
4. Zoran Jovanović, Matjaž Spreitzer, Urška Gabor, Danilo Suvorov, "Control of SrO buffer-layer formation on Si(001) using the pulsed-laser deposition technique", RSC advances, vol. 6, issue 85, str. 82150-82156, 2016, doi: 10.1039/c6ra16311d.

5. Mario Kurtjak, Marija Vukomanović, Andraž Krajnc, Lovro Kramer, Boris Turk, Danilo Suvorov, "Designing Ga(III)-containing hydroxyapatite with antibacterial activity", RSC advances, vol. 6, iss. 114, str. 112839-112852, 2016, http://pubs.rsc.org/en/content/articlepdf/2016/ra/c6ra23424k, doi: 10.1039/C6RA23424K.
6. Nemanja Aničić, Marija Vukomanović, Danilo Suvorov, "The nano-texturing of MgO microrods for antibacterial applications", RSC advances, 6(104), str. 102657-102664, 2016, doi: 10.1039/C6RA23058J.

Awards and Appointments

1. Urška Gabor: Award for best oral presentation in young researchers section at the 24th International Conference on Materials and Technology, Portorož, Metals and Technology (IMT), "Different approaches to avoiding lead deficiency in PMN-PT thin films"
2. Martin Štefanič: Seal of Excellence, Brussels, Belgium, European Commission, project proposal NanoDryCell: Nanoparticle-assisted desiccation of mesenchymal stem cells for the "off-the-shelf" allogeneic cell therapy

Organization of conferences, congresses and meetings

1. Workshop on M.ERA-NET project "ENPIEZO: Enabling technology for high-quality piezoMEMS", Taipei, Taiwan, 21. – 28. 2. 2016 (co-organizers)
2. Workshop on "EUDP Clean TechBlock II" project, Aalborg, Denmark, 29. 2. - 4. 3. 2016 (co-organizers)
3. Workshop on M.ERA-NET project "HarvEnPiez: Innovative nano-materials and architectures for integrated piezoelectric energy harvesting application", Ljubljana, 25. – 26. 8. 2016
4. Workshop on M.ERA-NET project "ENPIEZO: Enabling technology for high-quality piezoMEMS", Oslo, Norway, 31. 8. – 3. 9. 2016 (co-organizers)
5. COST TO-BE (Towards Oxide - Based Electronics) Fall Meeting 2016, Ljubljana, 28. – 30. 9. 2016
6. 24. International Conference on Materials and Technology, Portorož, 28. – 30. 9. 2016 (co-organizers)

INTERNATIONAL PROJECTS

1. Thin-Film-Energy-Storage Device on the basis of PLZT and Cu-Electrodes
   Prof. Danilo Suvorov, doc. dr. Matjaž Spreitzer
   Epcos Ohg
2. Investigation of Rare Earth Alloys and Related Compounds
   Prof. Danilo Suvorov, doc. dr. Srečo Škapin
   Urban Mining Company
3. Investigation of Rare Earth Alloys and Related Compounds
   Prof. Danilo Suvorov, doc. dr. Srečo Škapin
   Urban Mining Company
4. COST MP1308; Towards Oxide Based Electronics (TO-BE)
   Asst. Prof. Matjaž Spreitzer
   Cost Office
5. COST 1308 TO BE Workshop, Ljubljana, Slovenia, 28.-30.9.2016
   Asst. Prof. Matjaž Spreitzer
   Cost Office
6. Gold/Ferrite Nanocomposites: Antimicrobial and Magnetic Properties for Biomedical Applications
   Marija Vukomanović
   Slovenian Research Agency
7. Thermoelectric Materials based on Layered Crystal Structures
   Asst. Prof. Boštjan Jančar
   Slovenian Research Agency

RESEARCH PROGRAM

1. Contemporary Inorganic Materials and Nanotechnologies
   Prof. dr. Danilo Suvorov

R & D GRANTS AND CONTRACTS

1. Engineering of structural and microstructural characteristics in contemporary dielectrics and ferroelectrics with perovskite and perovskite-like crystal structures
   Prof. Danilo Suvorov
2. Growth of high quality piezoelectric thin films on silicon using pulsed laser deposition
   Asst. Prof. Matjaž Spreitzer
3. Development of heterogeneous catalysts for oxidative dehydrogenation of propane with CO
   Asst. Prof. Matjaž Spreitzer
4. SCOPES; Intelligent Scaffolds as a Tool for Advanced Tissue Regeneration
   Marija Vukomanović
   Snf- Swiss National Science Foundation
5. Cleantech Block II - Energy Saving Cladding
   Dr. Jakob König
   Eddp (eudp) Energy Technology Development
6. Enabling technology for high-quality piezoMEMS
   Asst. Prof. Matjaž Spreitzer
   MIZŠ

NEW CONTRACTS

1. Development and characterisation of mineral wool fibres
   Prof. Danilo Suvorov, dr. Jakob König
   Knauf Insulation, d. o. o., Škofja Loka
2. PBE Silent and PBE Varioface
   Prof. Danilo Suvorov, dr. Jakob König
   Knauf Insulation, d. o. o., Škofja Loka

VISITORS FROM ABROAD

1. Jelena Mitrić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 21.11. - 25.12.2016
2. Dr. Zoran Jovanović, Dr. Sonja Jovanović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 18.11. - 23.12.2016
3. Prof. Xiang Ming Chen, Institute of Materials Physics, School of Materials Science and Engineering, Zhejiang University, Hangzhou, China, 26. - 31. 8. 2016
4. Dr. Ioana Vlaicu, Dr. Raluca Negrea, National Institute of Materials Physics, Bucharest, Romania, 25. – 26. 8. 2016
5. Dr. Olga Plopa, Intelectro Iasi SRL, Romania, 25. – 26. 8. 2016
6. Dr. Eugene Kotomin, University of Latvia, Riga, Latvia, 25. – 26. 8. 2016
7. Dr. Sonja Jovanović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 24. 7. - 21. 8. 2016
8. Dr. Jyoti Prosad Guha, Missoury University of Science and Technology, Rolla, USA, 26.6. – 23. 9. 2016
9. Dr. Manfred Schweinzger, Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 24.6.2016.
10. Dr. Maja Đekić, Amra Salčinović, University of Sarajevo, Sarajevo, Bosnia and Herzegovina, 19. - 29.6.2016
11. Prof. Yuanzheng Yue, Dr. Rasmus R. Petersen, Martin B. Østergaard, Aalborg University & Jacob H. Bendtsen, Peter Matzen, Gråsten Brickwork, Denmark, 15.6.2016
12. Dr. Kerstin Schmoltner, TDK EPCOS, Deutschlandsberg, Austria, 1.- 2.6.2016
13. Dr. Bratislav Antić, Vinča Institute of Nuclear Sciences, Belgrade, Serbia, 20. - 23. 4. 2016

14. Dr. Sonja Jovanović, Vinča Institute of Nuclear Sciences, Belgrade, Serbia 12. – 25. 4. 2016
15. Dr. Chao-Ting Chen, National Taiwan University, Taipei City, Taiwan, 20. – 27. 3. 2016

Visiting Researchers

1. Dr. Jyoti Prosad Guha, Missoury University of Science and Technology, Rolla, USA, 26.6. – 23. 9. 2016
2. Dr. Daniel Diaz Fernandez, Universidad Autónoma de Madrid, Spain, 1. 10. 2015 – 30. 9. 2017

STAFF

Researchers

1. Asst. Prof. Boštjan Jančar
2. Dr. Jakob König
3. Dr. Špela Kunej
4. Dr. Marjeta Maček Kržmanc
5. Dr. Matjaž Spreitzer
6. **Prof. Danilo Suvorov, Head**
7. Asst. Prof. Srečo Davor Škapin
8. Dr. Marija Vukomanović

Postdoctoral associates

9. *Dr. Mojca Otoničar, 01.05.16, transferred to Department K5*
10. Dr. Martin Štefanič
11. *Dr. Vojka Žunič, left 01.04.16*

Postgraduates

12. Nemanja Aničić, B. Sc.
13. Alja Čontala, B. Sc.
14. Urška Gabor, B. Sc.
15. *Mario Kurtjak, B. Sc., left 01.09.16*
16. Tjaša Parkelj, B. Sc.
17. Tilen Sever, B. Sc.

Technical officers

18. David Fabijan, B. Sc.
19. *Dr. Jana Ferčič, left 01.07.16*
20. Damjan Vengust, B. Sc.

Technical and administrative staff

21. Vesna Butinar, B. Sc.
22. *Maja Šimaga, M. Sc., 01.12.16, transferred to Department B3*
23. Silvo Zupančič

BIBLIOGRAPHY

Original Article

1. Nemanja Aničić, Marija Vukomanović, Danilo Suvorov, "The nano-texturing of MgO microrods for antibacterial applications", *RSC advances,* vol. 6, iss. 104, pp. 102657-102664, 2016.
2. Marja Jerič, Johannes de Boor, Boštjan Jančar, Miran Čeh, "An enhanced thermoelectric figure of merit for $Sr(Ti_{0.8}Nb_{0.2})O_3$ based on a Ruddlesden-Popper-polytype-induced microstructure", *J. Eur. Ceram. Soc.*, vol. 36, nol. 5, pp. 1177-1182, 2016.
3. Zoran Jovanović, Matjaž Spreitzer, Urška Gabor, Danilo Suvorov, "Control of SrO buffer-layer formation on Si(001) using the pulsed-laser deposition technique", *RSC advances*, vol. 6, issue 85, pp. 82150-82156, 2016.
4. Luka Kelhar, Jana Bezjak, Pascal Boulet, Marjeta Maček, Sašo Šturm, Martin Lamut, Boštjan Markoli, Spomenka Kobe, Jean-Marie Dubois, "Stabilisation of Ce-Cu-Fe amorphous alloys by addition of Al", *Philos. mag. (2003)*, vol. 96, iss. 30, pp. 3143-3185, 2016.
5. Andraž Kocjan, Marko Češnovar, Damjan Vengust, Tomaž Kosmač, Aleš Dakskobler, "Translucent yttria- and silica-doped mullite ceramics with anisotropic grains produced by spark plasma sintering", *J. Am. Ceram. Soc.*, vol. 99, iss. 9, pp. 3090-3069, 2016.
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